

Section 12.0 Useful Tables

<https://nuclearweaponarchive.org/Nwfaq/Nfaq12.html>

Nuclear Weapons Frequently Asked Questions

Version 2.04: 5 April 2023

COPYRIGHT CAREY SUBLETTE

This material may be excerpted, quoted, or distributed freely provided that attribution to the author (Carey Sublette), the document name (Nuclear Weapons Frequently Asked Questions) and this copyright notice is clearly preserved, and the URL of this website is included: <http://nuclearweaponarchive.org>

Only authorized host sites may make this document publicly available on the Internet through the World Wide Web, anonymous FTP, or other means.

Unauthorized host sites are expressly forbidden.

The only authorized host site for the NWFAQ in English is the [Nuclear Weapon Archive \(http://nuclearweaponarchive.org\)](http://nuclearweaponarchive.org)

[Back to Main Index](#)

12.0 Useful Tables

CONVERSION FACTORS

Unit	Equivalent To
1 kt	10 ¹² calories
	4.19x10 ¹² joules
	4.19x10 ¹⁹ ergs
	2.62x10 ³¹ eV
	2.62x10 ²⁵ MeV
	fission of 0.241 moles of material (1.45x10 ²³ nuclei)
	fission of approx. 57 g of material
1 eV	1.16x10 ⁶ kilowatt-hrs
	3.97x10 ⁹ BTU
	1.602177 x 10 ⁻¹² erg
	11606 degree K
1 Bar	10 ⁵ pascals (nt/m ²)
	10 ⁶ dyne/cm ²
	0.98687 atmospheres
	14.5038 PSI
1 calorie	4.1868 J

Convenient Energy Content Approximations

Fission of Th-232: 16.77 kt/kg

Fission of U-233: 17.89 kt/kg

Fission of U-235: 17.74 kt/kg

Fission of U-238: 17.27 kt/kg

Fission of Pu-239: 18.29 kt/kg

Fission of Pu-241: 18.10 kt/kg

Based on: Sher, R.; Beck, C. 1981. Fission Energy Release for 16 Fissioning Nuclides. NP-1771. Stanford University, Department of Mechanical Engineering, March 1981

Fusion of pure deuterium: 82.2 kt/kg

Fusion of tritium and deuterium (50/50): 80.4 kt/kg

Fusion of lithium-6 deuteride: 64.0 kt/kg

Fusion of lithium-7 deuteride: TBD

Total conversion of matter to energy: 21480.7643 kt/kg

Fission of 1.11 g U-235: 1 megawatt-day (thermal)

IMPORTANT UNITS OF MEASUREMENT

Quantity Measured	Unit	Symbol	Formula
Microscopic Cross Section	Barn	b	10^{-24} cm^2
Radioactivity	Becquerel	Bq	1 decay/sec
	Curie	Ci	3.7×10^{10} decay/sec
Absorbed Radiation Dose	Gray	Gy	1 J/Kg
	Rad	None	100 erg/g (.01 J/Kg)
Biological Equivalent Dose	Sievert	Sv	Grays*Q
	Rem	None	Rads*RBE
Absorbed Gamma/X-Ray Dose	Roentgen	R	94 erg/g
Immediate Explosive Energy	Kiloton	kt	10^{12} calories
Radiation Biological Effect	None	RBE	
Radiation Quality Factor	None	Q	
Pressure	Bar	None	10^5 pascals (nt/m ²)

PHYSICAL CONSTANTS

[All constants are exact to the precision given]

Quantity	Symbol	Value	Unit
Speed of Light in Vacuum	c	$2.99792458 \times 10^{10}$	cm/sec
Planck Constant	h	6.62608×10^{-27}	erg-sec
Avogadro Constant	N _A	6.02214×10^{23}	atom/mole
Molar Gas Constant	R	8.3145×10^7	erg/(mole K)
Boltzmann Constant	k	1.3806×10^{-16}	erg/K
Stefan-Boltzmann Constant	sigma	5.670×10^{-5}	erg/cm ² K ⁴ sec
Perfect Gas Standard Volume	V ₀	2.2414×10^5	cm ³
Atomic Mass Constant	m ₀	1.66054×10^{-24}	g
	m ₀	9.31494×10^8	eV

Fissionable/Fissile Isotope Properties

Isotope	Half-Life (years)	Primary Decay Mode	Spontaneous Fission Rate - SF (F/sec/kg)	Fission Cross Section - sigma (barns, fission spectrum avg)	SF Neutron Multiplicity - nu _{SF} (n/fission)	Fission Spectrum Neutron Multiplicity - nu _{FS} (n/fission)	Critical Mass - M _c (kg)	Decay Heat - Q (W/kg)	Specific Activity (curies/kg)
Th-232	1.405 x 10 ¹⁰	Alpha 4.083 MeV	<5 x 10 ⁻⁵	0.0785	-	2.16	None	2.654 x 10 ⁻⁶	1.097 x 10 ⁻⁴
Pa-231	32,760	Alpha 5.149 MeV	<5	0.834	-	2.457	>188	1.442	47.23
U-232	68.9	Alpha 5.414 MeV	2 x 10 ⁻³	2.013	2	3.296	>5	717.6	22,360
U-233	159,200	Alpha 4.909 MeV	-	1.946	-	2.649	16	0.2804	9.636
U-234	245,500	Alpha 4.859 MeV	3.9	1.223	1.8	2.578	>41	0.1792	6.222
U-235	7.038 x 10 ⁸	Alpha 4.679 MeV	5.6 x 10 ⁻³	1.235	2.0	2.6055	48	5.994 x 10 ⁻⁵	2.161 x 10 ⁻³
U-236	2.342 x 10 ⁷	Alpha 4.572 MeV	2.30	0.594	1.8	2.526	>167	1.753 x 10 ⁻³	0.06467
U-238	4.468 x 10 ⁹	Alpha 4.270 MeV	5.51	0.308	1.97 +- 0.07	2.6010	None	8.508 x 10 ⁻⁶	3.361 x 10 ⁻⁴
Np-237	2.144 x 10 ⁶	Alpha 4.959 MeV	< 0.05	1.335	2	2.889	75-105	0.02068	0.7034
Pu-238	87.7	Alpha 5.593 MeV	1.204 x 10 ⁶	1.994	2.28 +- 0.10	3.148	9	5.678 x 10 ⁵	17,120

Pu-239	24,110	Alpha 5.245 MeV	10.1	1.800	2.9	3.1231	10.5	1.929	62.03
Pu-240	65,640	Alpha 5.256 MeV	478,000	1.357	2.189 +- 0.026	3.061	40	7.07	227
Pu-241	14.35	Beta 0.021 MeV	<0.8	1.648	-	3.142	12	129.4	1.033 x 10 ⁵
Pu-242	373,300	Alpha 4.984 MeV	805,000	1.127	2.28 +- 0.13	3.070	95, range 75- 100	0.1169	3.956
Am-241	432.2	Alpha 5.638 MeV	500	1.378	2	3.457	83.5	114.7	3,431
Cf-251	898	Alpha 6.176 MeV	-	2.430	-	4.560	1.94	58.05	1,586

Isotope Properties and Neutron Cross Sections

This subsection lists most isotopes of interest for direct, indirect, or theoretical nuclear weapon applications. Basic isotopes characteristics, and summary tables of significant neutron reaction cross sections are included.

The neutronic data is derived from the authoritative ENDF-VI evaluated nuclear data base compiled and maintained by the [National Nuclear Data Center \(NNDC\)](#) at the [Brookhaven National Laboratory \(BNL\)](#). The data listings below were prepared with the assistance of the [Japan Atomic Energy Research Institute \(JAERI\)](#).

Notes:

- The Maxwellian average cross sections are for a peak neutron energy distribution at 0.0253 eV (a room temperature thermal distribution).
- Molar volume is the minimum volume per mole for the densest phase at standard pressure and temperature (STP)
- SF = spontaneous fission
- Critical mass estimates for the fissile isotopes are given for bare spheres at the densest STP phase. Where available these estimates are from other sources and are based either on actual experimental measurement, or reasonably

sophisticated numerical computations. All fissile isotopes also include for comparison critical mass estimates made by me, using an exact criticality solution with a one-group representation of neutronic properties. The one-group parameters are fission spectrum averages calculated from the ENDF-VI evaluated nuclear data base.

As can be seen where outside critical mass estimates are also available, this one-group calculation method consistently underestimates the true critical mass - primarily because it does not take into account the effects of inelastic scattering in softening the neutron spectrum. The one-group calculated critical mass estimates are thus lower bounds on the true value. Comparison between the one-group calculations and the actual values for the highly fissile isotopes for which good experimental data is available (U-233, U-235, Pu-239, and Pu-241) shows a consistent underestimate of 70-75% of the true value. For less fissile isotopes, where critical mass estimates have been offered by others (these are mostly calculated estimates also, but with more sophisticated models), the underestimates are more severe (at worst 22-29% of the 'true' value for Pu-242). This too is to be expected because the effects of inelastic scattering is relatively greater in less fissile materials. On the other hand, the estimates for extremely fissile transuranics like the californium isotopes should be quite good.

Sources:

H. C. Paxton and N. L. Pruvost, *Critical Dimensions of Systems Containing 235-U, 239-Pu, and 233-U; 1986 Rev.*, LA-10860-MS, Los Alamos (July 1987), p. 96-104.

Hugh C. Paxton, "Fast Critical Experiments," *Progress in Nuclear Energy* Vol. 7 (1981), p. 154.

Samuel Glasstone and Leslie M. Redman, *An Introduction to Nuclear Weapons*, WASH-1037 Revised. U.S. Atomic Energy Commission, Division of Military Applications, June 1972, pg. 12.

Amory Lovins, "Nuclear Weapons and Power-Reactor Plutonium", *Nature*, Vol.283, 28 Feb 1980, pp. 817-823

Alexander De Volpi, *Proliferation, Plutonium and Policy: Institutional and Technological Impediments to Nuclear Weapons Propagation*, Pergamon (1979), pg. 86.

C. C. Byers, D. E. Hansen, J. J. Koelling, E. A. Plassmann, D. R. Smith, *Reactivity Coefficients of Heavy Isotopes In LASL's-Fast Critical Assemblies*, LA-UR-78-427, Los Alamos (June 1978), pg. 2.

Evaluation of nuclear criticality safety data and limits for actinides in transport, C4/TMR2001/200-1, IRSN (L'Institut de radioprotection et de sûreté nucléaire), 2001.

Neptunium criticality achieved, http://www.lanl.gov/news/index.php?fuseaction=home.story&story_id=1348

Hydrogen

- Atomic number: 1
- Molar volume: 13.1 cm³/mole (solid, 13 K)
- Density: 0.0763 (solid, 13 K, natural hydrogen)
- Melting point: 13.96 K (natural hydrogen)
- Boiling point: 20.39 K

1-H-1

- Atomic Mass: 1.007825032 +- 0.000000000 (amu)
- Excess Mass: 7288.969 +- 0.001 keV
- Binding Energy: 0.000 +- 0.000 keV
- Stable Isotope
- Atomic Percent Abundance: 99.985%
- >Magnetic Moment: 2.7928 nuclear magnetons
- Spin: 1/2+

Lightest possible atom, and consequently the most efficient neutron moderator. Widely used in nuclear weapon structural materials (i.e. plastics). Due to moderating ability and light weight, used to harden weapons against outside neutron fluxes (especially in combination with Li-6).

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	20.81	20.78		692.0 -3	3.927
elastic	20.47	20.47		692.0 -3	3.926
capture	332.0 -3	294.2 -3	149.1 -3	29.83 -6	39.27 -6

1-H-2 (Deuterium)

- Atomic Mass: 2.014101778 +- 0.000000000 (amu)
- Excess Mass: 13135.720 +- 0.001 keV
- Binding Energy: 2224.573 +- 0.002 keV
- Stable Isotope
- Atomic Percent Abundance: 0.015%
- Spin: 1+
- Magnetic Moment: 0.8574 nuclear magnetons
- Quadrupole Moment: 0.003 barns

Best nuclear reactor moderator due to high moderating efficiency and extremely low absorption cross section. A principal fusion fuel in thermonuclear weapons, can also be used for fusion boosting, and in neutron generators. Melting point 20.4 K, boiling point 23.67 K.

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	3.390	3.390		801.5 -3	2.537
elastic (n,2n)	3.389	3.390 (E-thr = 3.339 MeV)		624.3 -3	2.532
capture	550.0 -6	487.4 -6	286.3 -6	177.2 -3	5.276 -3
				9.521 -6	7.076 -6

1-H-3 (Tritium)

- Atomic Mass: 3.016049268 +- 0.000000001 (amu)
- Excess Mass: 14949.794 +- 0.001 keV
- Binding Energy: 8481.821 +- 0.004 keV
- Beta Decay Energy: B- 18.591 +- 0.001 keV
- Half Life: 12.33 years
- Specific Activity: 9613 curie/g
- Radioisotopic Power: 1.059 W/g
- Primary Mode of Decay: Beta to He-3
 - Decay Energy: B- 18.591 +- 0.001 keV
- Magnetic Moment: 2.9789 nuclear magnetons
- Spin: 1/2+

A principal thermonuclear fuel, best used in conjunction with deuterium (the D+T reaction is the easiest by far to ignite, as well as one of the most energetic). It is produced in place by tritium breeding reactions in thermonuclear weapons. It can also be manufactured and loaded into weapons (with deuterium) for use in fusion boosting of

fission weapons, as the neutron source in neutron bombs and neutron generators for commercial or weapons use. Tritium is a pure beta emitter. Due to weak radiation emissions, it is used in safe luminescent displays. This nuclide is useful for thickness gauge of thin plastics.

Helium

- Atomic number: 2
- Molar volume: 32.05 cm³/mole (liquid, 4.125 K)
- Density: 0.1249 (liquid, 4.125 K, natural helium)
- Boiling point: 4.125 K

2-He-3

- Atomic Mass: 3.016029310 +- 0.000000001 (amu)
- Excess Mass: 14931.204 +- 0.001 keV
- Binding Energy: 7718.058 +- 0.002 keV
- Stable Isotope
- Atomic Percent Abundance: 0.000137%
- Magnetic Moment: -2.1276 nuclear magnetons
- Spin: 1/2+

This isotope is produced by the decay of tritium and so accumulates in fusion boosting reservoirs as an undesirable contaminant due to its high neutron absorption. It can be recycled to produce tritium by neutron bombardment. It is a valuable fusion fuel produced (and consumed) in the course of deuterium-deuterium fusion. Very rare in nature.

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	5.331 +3	4.743 +3		1.168	2.941
elastic	3.135	3.135		954.4 -3	2.121
nonelastic	5.328 +3	4.722 +3	2.381 +3	213.8 -3	819.6 -3
capture	54.01 -6	47.88 -6	246.9 -6	35.18 -6	39.24 -6
(n,p)	5.328 +3	4.722 +3	2.381 +3	139.7 -3	816.9 -3
(n,d)		(E-thr =	4.362 MeV)	74.07 -3	2.647 -3

2-He-4

- Atomic Mass: 4.002603250 +- 0.000000001 (amu)
- Excess Mass: 2424.911 +- 0.001 keV
- Binding Energy: 28295.673 +- 0.005 keV

- Beta Decay Energy: B- -22895.261 +- 212.132 keV
- Stable Isotope
- Atomic Percent Abundance: 99.999863%
- Magnetic Moment: 0.8220 nuclear magnetons
- Quadrupole Moment: -0.001 barns
- Spin: 0+

Most common natural isotope of helium. Widely used in industry as an inert gas. Produced as an end product of fusion reactions. This isotope has a zero cross section for all neutron reactions except scattering for neutron energies below 20 MeV.

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	759.3 -3	759.3 -3		1.052	3.685
elastic	759.3 -3	759.3 -3		1.052	3.685

Lithium

- Atomic number: 3
- Molar volume: 13.0 cm³/mole
- Density: 0.534
- Melting point: 180.54 C
- Boiling point: 1342 C

3-Li-6

- Atomic Mass: 6.015122281 +- 0.000000510 (amu)
- Excess Mass: 14086.312 +- 0.475 keV
- Binding Energy: 31994.564 +- 0.475 keV
- Beta Decay Energy: B- -4288.153 +- 5.448 keV
- Stable Isotope
- Atomic Percent Abundance: 7.42%
- Spin: 1+
- Magnetic Moment: 0.8220 nuclear magnetons
- Quadrupole Moment: -0.001 barns

Natural lithium isotope used as a thermonuclear weapon fusion fuel, in the form of lithium deuteride, due to its production of tritium through the (n,t) reaction. The very high cross section of this reaction for thermalized neutrons, combined with the light weight of the Li-6 atom, make it useful in the form of lithium hydride for hardening of nuclear weapons against external neutron fluxes.

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	941.1	837.2		1.431	1.900
elastic	734.5 -3	735.2 -3		906.4 -3	1.422
nonelastic	940.4	836.5	427.5	525.0 -3	478.0 -3
inelastic		(E-thr =	1.751 MeV)	412.0 -3	142.8 -3
(n,2n)		(E-thr =	6.614 MeV)	78.05 -3	190.5 -6
capture	38.50 -3	34.11 -3	17.47 -3	82.11 -6	28.06 -6
(n,p)		(E-thr =	3.185 MeV)	6.766 -3	4.264 -3
(n,t)	940.3	833.4	424.9	28.04 -3	330.7 -3

3-Li-7

- Atomic Mass: 7.016004049 +- 0.000000507 (amu)
- Excess Mass: 14907.673 +- 0.473 keV
- Binding Energy: 39244.526 +- 0.473 keV
- Beta Decay Energy: B- -861.815 +- 0.018 keV
- Stable Isotope
- Atomic Percent Abundance: 92.58%
- Spin: 3/2-
- Magnetic Moment: 3.2564 nuclear magnetons
- Quadrupole Moment: -0.040 barns

Predominant isotope of natural lithium. Due to the large cross section for the (n,t) reaction at high neutron energies this isotope can breed substantial quantities of tritium in a fusion-driven chain reaction and thus serve as a fusion fuel. Although less efficient than Li-6 for this purpose, and not used in modern thermonuclear weapons it served this function in some early high yield weapons.

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	1.015	1.012		1.470	1.845
elastic	970.0 -3	971.7 -3		1.025	1.660
nonelastic	45.40 -3	40.38 -3	1.078	444.9 -3	184.8 -3
inelastic		(E-thr =	0.546 MeV)	365.0 -3	184.7 -3
(n,2n)		(E-thr =	8.300 MeV)	70.09 -3	38.53 -6
capture	45.40 -3	40.24 -3	20.43 -3	1.930 -6	6.903 -6
(n,d)		(E-thr =	8.868 MeV)	9.763 -3	10.98 -6
total (n,t)		(E-thr =	2.822 MeV)	302.9 -3	20.04 -3

Beryllium

- Atomic number: 4

- Molar volume: 4.8775 cm³/mole
- Density: 1.8477
- Melting point: 1287 C
- Boiling point: 2470 C

4-Be-9

- Atomic Mass: 9.012182135 +- 0.000000425 (amu)
- Excess Mass: 11347.584 +- 0.396 keV
- Binding Energy: 58164.907 +- 0.396 keV
- Beta Decay Energy: B- -1068.116 +- 0.899 keV
- Stable Isotope
- Atomic Percent Abundance: 100%
- Spin: 3/2-

Beryllium is both an excellent neutron reflector and moderator, and is in addition very light. It has one of the highest neutron scattering cross sections per unit volume, and has very low neutron absorption. Beryllium is commonly used as a neutron reflector to make compact light-weight fission weapons. Beryllium also undergoes (n,2n) neutron multiplication reactions, which are not important for fission-spectrum neutrons, but may have a significant role in fusion boosted systems. Beryllium can also generate neutrons through Be-9(γ ,n)Be-8 and Be-9(a,n)C-12 reactions. When combined with an isotope that is a strong alpha-emitter but a weak gamma-emitter (usually Po-210), Be has been used in modulated neutron initiators for fission weapons. Pu-239/Be sources have been used as convenient laboratory neutron sources; Ra-226/Be and Am-241/Be neutron sources are useful for moisture gauges.

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	6.159	6.158		1.494	2.834
elastic	6.151	6.151		959.3 -3	2.673
nonelastic	7.600 -3	6.754 -3	1.164	534.5 -3	161.1 -3
inelastic		(E-thr = 8.784 MeV)		22.90 -3	38.95 -6
(n,2n)		(E-thr = 1.868 MeV)		269.1 -3	53.83 -3
(n,2na)		(E-thr = 1.749 MeV)		17.49 -3	4.938 -3
(n,2n) to 1st		(E-thr = 2.701 MeV)		168.6 -3	66.50 -3
(n,2n) to 2nd		(E-thr = 7.561 MeV)		28.68 -3	133.4 -6
capture	7.600 -3	6.735 -3	3.419 -3	323.1 -9	1.156 -6
(n,p)		(E-thr = 14.260 MeV)			20.25 -9
(n,d)		(E-thr = 16.300 MeV)			32.68 -9
(n,t)		(E-thr = 11.610 MeV)		18.36 -3	2.751 -6
(n,a)		(E-thr = 0.670 MeV)		9.419 -3	35.65 -3

Boron

- Atomic number: 5
- Molar volume: 4.39 cm³/mole (alpha form, 25 C)
- Density: 2.46 (alpha form)
- Melting point: 2076 C
- Boiling point: 3900 C (estimated)

5-B-10

- Atomic Mass: 10.012937027 +- 0.000000397 (amu)
- Excess Mass: 12050.761 +- 0.370 keV
- Binding Energy: 64750.700 +- 0.370 keV
- Beta Decay Energy: B- -3647.807 +- 0.091 keV
- Stable Isotope
- Atomic Percent Abundance: 19.9%
- Spin: 3+

This natural isotope is the best absorber of fast neutrons, and an excellent absorber of slow neutrons. As a component of natural boron, it is commonly used as a neutron absorber (control rod or burnable poison) in nuclear reactors. The separated isotope has been used to harden nuclear weapons against external neutron fluxes, and to reduce the neutron preheating of fusion stages by fission triggers in thermonuclear weapons. Use of B-10 has been proposed to create "clean" (low fallout and low neutron emission) thermonuclear weapons.

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	3.840 +3	3.415 +3		1.467	2.638
elastic	2.144	2.144		942.5 -3	2.062
nonelastic	3.838 +3	3.413 +3	1.726 +3	524.2 -3	575.3 -3
inelastic		(E-thr =	0.791 MeV)	268.5 -3	70.84 -3
(n,2n)		(E-thr =	8.980 MeV)	26.83 -3	33.22 -6
capture	500.0 -3	443.1 -3	224.9 -3	21.26 -6	76.03 -6
(n,p)	3.000 -3	2.659 -3	94.96 -3	37.51 -3	15.25 -3
(n,d)		(E-thr =	4.801 MeV)	47.63 -3	1.249 -3
(n,a)	3.837 +3	3.400 +3	1.719 +3	48.95 -3	435.5 -3
(n,t2a)	12.00 -3	10.63 -3	305.2 -3	94.66 -3	52.28 -3

5-B-11

- Atomic Mass: 11.009305466 +- 0.000000451 (amu)
- Excess Mass: 8667.984 +- 0.420 keV
- Binding Energy: 76204.800 +- 0.421 keV
- Beta Decay Energy: B- -1982.547 +- 0.854 keV
- Stable Isotope
- Atomic Percent Abundance: 80.1%

- Spin: 3/2-

B-11 is the majority component of natural boron, and thus appears in boron mixtures used for nuclear applications where B-10 has not been separated.

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	5.050	5.050		1.415	2.425
elastic	5.045	5.045		934.9 -3	2.396
inelastic		(E-thr = 2.320 MeV)		298.3 -3	28.81 -3
(n, 2n)		(E-thr = 12.510 MeV)		1.414 -3	496.7 -9
(n, na)		(E-thr = 9.460 MeV)		101.0 -3	27.54 -6
(n, np)		(E-thr = 12.260 MeV)		1.104 -3	211.0 -9
(n, n2a)		(E-thr = 12.150 MeV)		17.96 -3	3.696 -6
(n, nd)		(E-thr = 17.270 MeV)			1.335 -9
(n, nt)		(E-thr = 12.250 MeV)		747.4 -6	169.8 -9
capture	5.075 -3	4.513 -3	2.542 -3	0.000	5.473 -6
(n, p)		(E-thr = 11.710 MeV)		4.021 -3	579.7 -9
(n, d)		(E-thr = 9.830 MeV)		9.200 -3	4.074 -6
(n, t)		(E-thr = 10.430 MeV)		14.96 -3	3.443 -6
(n, a)		(E-thr = 7.240 MeV)		31.38 -3	63.13 -6

Cobalt

- Atomic number: 27
- Molar volume: 6.61 cm³/mole (25 C)
- Density: 8.92 (25 C)
- Melting point: 1493 C
- Boiling point: 2930 C

27-Co-59

- Atomic Mass: 58.9332002 +- 0.0000015 amu
- Excess Mass: -62223.609 +- 1.420 keV
- Binding Energy: 517308.113 +- 1.422 keV
- Beta Decay Energy: B- -1072.484 +- 0.561 keV
- Stable Isotope
- Atomic Percent Abundance: 100%
- Spin: 7/2-

Although the concept of the enhanced fallout "cobalt bomb", in which radioactive Co-60 is produced by fusion neutrons, is well known this isotope is not known to have been seriously considered for weapons applications. The 5.26 year half-life of Co-60 is too long to be of real military interest, which favors more intense shorter term effects.

REACTION	2200-m/s	Maxw.Avg.	Res.Integ	14-MeV	Fiss.Avg.
----------	----------	-----------	-----------	--------	-----------

	(barns)	(barns)	(barns)	(barns)	(barns)
total	43.19	38.98		2.653	3.678
elastic	6.018	6.018		1.265	3.015
inelastic		(E-thr = 1.118 MeV)		542.3 -3	655.5 -3
(n,2n)		(E-thr = 10.630 MeV)		690.0 -3	180.0 -6
(n,na)		(E-thr = 7.069 MeV)		1.765 -3	558.8 -9
(n,np)		(E-thr = 7.496 MeV)		61.93 -3	56.52 -6
capture	37.18	32.96	75.51	1.121 -3	5.704 -3
(n,p)		(E-thr = 0.796 MeV)		53.00 -3	1.484 -3
(n,d)		(E-thr = 5.233 MeV)		5.673 -3	2.480 -6
(n,a)	0.000	0.000	20.24 -3	32.20 -3	165.1 -6

Tantalum

- Atomic number: 73
- Molar volume: 10.84 cm³/mole
- Density: 16.69
- Melting point: 2996 C
- Boiling point: 5429 C

73-Ta-181

- Atomic Mass: 180.9479963 +- 0.0000031 amu
- Excess Mass: -48441.085 +- 2.892 keV
- Binding Energy: 1452238.715 +- 2.903 keV
- Beta Decay Energy: B- -187.890 +- 4.549 keV
- Stable Isotope
- Atomic Percent Abundance: 99.988%
- Spin: 7/2+

Comprising nearly all of natural tantalum, this isotope was studied for possible use in enhanced fallout radiation weapons by the U.S. in the 1950s. Compared with Co-60 the shorter half-life of Ta-182 (115 days vs 2.56 years) and the higher cross section for epithermal neutrons made Ta-181 a more desirable candidate for this use.

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	26.32	24.02		5.370	7.005
elastic	5.650	5.640		2.991	4.614
inelastic		(E-thr = 0.006 MeV)		241.9 -3	2.295
(n,2n)		(E-thr = 7.686 MeV)		2.133	5.149 -3
(n,3n)		(E-thr = 14.300 MeV)			6.300 -6
(n,np)		(E-thr = 5.968 MeV)		163.1 -6	55.01 -9
capture	20.67	18.38	660.0	205.5 -9	85.66 -3
(n,p)		(E-thr = 0.242 MeV)		3.723 -3	2.305 -6
(n,a)	45.94 -6	47.65 -6	1.579	116.4 -6	3.588 -3

Thorium

- Atomic number: 90
- Molar volume: 19.80 cm³/mole (25 C)
- Density: 11.72 (25 C)
- Melting point: 1842 C (+- 30 C)
- Boiling point: 4820 C

90-Th-232

- Atomic Mass: 232.0380504 +- 0.0000022 amu
 - Excess Mass: 35443.677 +- 2.036 keV
 - Binding Energy: 1766691.409 +- 2.061 keV
 - Beta Decay Energy: B- -494.958 +- 7.826 keV
 - Atomic Percent Abundance: 100%
 - Half Life: 1.405E10 Y
- Specific Activity: 1.097E-7 curie/g
 Radioisotopic Power: 2.654E-9 W/g
 Primary Mode of Decay: Alpha to Ra-228

- Decay Energy: 4.083 MeV

Secondary Mode of Decay: SF Spontaneous fission

- Branch ratio: <1.0E-9 %
 - SF rate (fissions/sec/g) = <4E-6
 - Neutron emission rate (N/sec/g) = <6E-6
- Spin: 0+
 - Critical mass: None

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	21.11	20.23		5.740	7.634
elastic	13.71	13.70		2.683	4.579
inelastic		(E-thr = 0.049 MeV)		726.0 -3	2.875
(n,2n)		(E-thr = 6.465 MeV)		1.181	14.46 -3
(n,3n)		(E-thr = 11.610 MeV)		800.0 -3	113.6 -6
fission	0.000	0.000	636.3 -3	350.0 -3	78.48 -3
capture	7.400	6.532	84.35	0.000	85.70 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 1.896
- Incident neutron 1E+05 eV Nu_p = 1.910

- Incident neutron 1E+06 eV Nu_p = 2.040
- Incident neutron 4E+06 eV Nu_p = 2.472
- Incident neutron 2E+07 eV Nu_p = 4.774
- Incident neutron fission spectrum average Nu_p = 2.159

Protactinium

- Atomic number: 91
- Molar volume: 15.18 cm³/mole (25 C)
- Density: 15.22 (Pa-231, 25 C)
- Melting point: 1568 - 1575 C
- Boiling point: unknown

91-Pa-231

- Atomic Mass: 231.0358789 +- 0.0000028 amu
- Excess Mass: 33420.973 +- 2.586 keV
- Binding Energy: 1759860.436 +- 2.605 keV
- Beta Decay Energy: B- -382.155 +- 3.220 keV
- Half Life: 32760 Y
- Specific Activity: 0.04723 curie/g
- Radioisotopic Power: 0.001442 W/g
- Primary Mode of Decay: Alpha to Ac-227
 - Decay Energy: 5.149 MeV

Secondary Mode of Decay: 24NEC

- Branch ratio: 13E-10 %

Tertiary Mode of Decay: Spontaneous fission

- Branch ratio: <=3E-10 %
- SF rate (fissions/sec/g) = <5E-3
- Neutron emission rate (N/sec/g) = <1E-2
- Spin: 3/2-
- Critical mass: Probably not fissile (C4/TMR2001/200-1), 188 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	210.7	189.2		5.746	7.515
elastic	9.961	9.815		2.556	4.165
inelastic		(E-thr = 0.009 MeV)		252.0 -3	2.231
(n,2n)		(E-thr = 6.844 MeV)		724.0 -3	5.849 -3
(n,3n)		(E-thr = 12.660 MeV)		134.0 -3	21.01 -6

fission	19.66 -3	16.99 -3	4.605	2.080	833.8 -3
capture	200.7	179.3	595.5	0.000	273.7 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 2.274
- Incident neutron 1E+05 eV Nu_p = 2.285
- Incident neutron 1E+06 eV Nu_p = 2.381
- Incident neutron 4E+06 eV Nu_p = 2.702
- Incident neutron 2E+07 eV Nu_p = 4.420
- Incident neutron fission spectrum average Nu_p = 2.457

Uranium

- Atomic number: 92
- Molar volume: 12.56 cm³/mole
- Density: 18.95 (alpha form, stable to 667.8 C)
- Melting point: 1132.2 C (+/- 0.8 C)
- Boiling point: 3818 degrees C
- specific heat 6.65 cal/mole/C (25 C)
- tensile strength 450 MPa

92-U-232

- Atomic Mass: 232.037146280 +- 0.000002857 (amu)
- Excess Mass: 34601.531 +- 2.662 keV
- Binding Energy: 1765968.847 +- 2.680 keV
- Beta Decay Energy: B- -2750.000 +- 100.000 keV
- Half Life: 68.9 Y
- Specific Activity: 22.36 curie/g
- Radioisotopic Power: 0.7176 W/g
- Primary Mode of Decay: Alpha to Th-228
 - Decay Energy: 5.414 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: = 2E-16 %
- SF rate (fissions/sec/g) = 2E-6
- Neutron emission rate (N/sec/g) = 4E-6
- Spin: 0+
- Critical mass: 3.57-3.70 kg (C4/TMR2001/200-1), 5.04 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
----------	---------------------	----------------------	----------------------	-------------------	----------------------

total	162.3	141.5		5.774	7.639
elastic	10.80	10.74		3.230	5.083
inelastic		(E-thr = 0.048 MeV)		19.42 -3	509.2 -3
(n,2n)		(E-thr = 7.286 MeV)		150.0 -3	484.1 -6
(n,3n)		(E-thr = 13.210 MeV)		5.000 -3	562.0 -9
fission	76.66	66.42	363.8	2.370	2.013
capture	74.88	64.38	172.9	0.000	28.47 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E+00 eV Nu_p = 3.126
- Incident neutron 1E+05 eV Nu_p = 3.136
- Incident neutron 1E+06 eV Nu_p = 3.233
- Incident neutron 4E+06 eV Nu_p = 3.554
- Incident neutron 1.5E+07 eV Nu_p = 4.732
- Incident neutron fission spectrum average Nu_p = 3.296

92-U-233

- Atomic Mass: 233.039628196 +- 0.000003010 (amu)
- Excess Mass: 36913.421 +- 2.804 keV
- Binding Energy: 1771728.280 +- 2.821 keV
- Beta Decay Energy: B- -1028.513 +- 51.640 keV
- Half Life: 159200 Y
Specific Activity: 0.009636 curie/g
Radioisotopic Power: 0.0002804 W/g
Primary Mode of Decay: Alpha to Th-229
 - Decay Energy: 4.909 MeV
- Spin: 5/2+
- Critical mass: 16 kg (LA-10860-MS; De Volpi; Hugh C. Paxton 1981), 11.63 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	588.4	522.2		5.920	7.665
elastic	11.97	11.94		2.889	4.447
inelastic		(E-thr = 0.041 MeV)		174.6 -3	1.198
(n,2n)		(E-thr = 5.779 MeV)		406.9 -3	4.078 -3
(n,3n)		(E-thr = 13.060 MeV)		2.049 -3	1.380 -6
fission	531.2	468.9	774.2	2.450	1.946
capture	45.25	41.34	138.4	13.71 -9	70.30 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 2.53E-05 eV Nu_p = 2.487
- Incident neutron 1E+05 eV Nu_p = 2.487

- Incident neutron 1E+06 eV Nu_p = 2.565
- Incident neutron 2E+06 eV Nu_p = 2.680
- Incident neutron 1.4E+07 eV Nu_p = 4.223
- Incident neutron fission spectrum average Nu_p = 2.649

92-U-234

- Atomic Mass: 234.040945606 +- 0.000002122 (amu)
- Excess Mass: 38140.580 +- 1.976 keV
- Binding Energy: 1778572.444 +- 2.002 keV
- Beta Decay Energy: B- -1809.846 +- 8.321 keV
- Atomic Percent Abundance: 0.0055%
- Half Life: 245500 Y
- Specific Activity: 0.006222 curie/g
- Radioisotopic Power: 0.0001792 W/g
- Primary Mode of Decay: Alpha to Th-230
 - Decay Energy: 4.859 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 1.7E-9 %
- SF rate (fissions/sec/g) = 3.9E-3
- Neutron emission rate (N/sec/g) = 7.2E-3
- Spin: 0+
- Critical mass: 145-149 kg (C4/TMR2001/200-1), 40.6 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	119.2	106.8		5.721	7.696
elastic	19.42	19.25		2.733	4.692
inelastic		(E-thr = 0.044 MeV)		320.2 -3	1.557
(n,2n)		(E-thr = 6.873 MeV)		473.0 -3	4.811 -3
(n,3n)		(E-thr = 12.650 MeV)		127.0 -3	14.54 -6
fission	6.218 -3	5.536 -3	6.718	2.067	1.223
capture	99.75	87.53	631.3	25.77 -6	217.7 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E+00 eV Nu_p = 2.339
- Incident neutron 1E+05 eV Nu_p = 2.353
- Incident neutron 1E+06 eV Nu_p = 2.474
- Incident neutron 4E+06 eV Nu_p = 2.879
- Incident neutron 1.5E+07 eV Nu_p = 4.369
- Incident neutron fission spectrum average Nu_p = 2.578

92-U-235

- Atomic Mass: 235.043923062 +- 0.000002115 (amu)
- Excess Mass: 40914.062 +- 1.970 keV
- Binding Energy: 1783870.285 +- 1.996 keV
- Beta Decay Energy: B- -123.716 +- 0.869 keV
- Atomic Percent Abundance: 0.720%
- Spin: 7/2- 7
- Half Life: 7.038E8 Y
- Specific Activity: 2.161E-6 curie/g
- Radioisotopic Power: 5.994E-8 W/g
- Primary Mode of Decay: Alpha to Th-231
 - Decay Energy: 4.679 MeV

Primary Mode of Decay: Spontaneous fission

- Branch ratio: 7.0E-9%
- SF rate (fissions/sec/g) = 5.6E-6
- Neutron emission rate (N/sec/g) = 1.1E-5
- Meta state at 0.000 Mev
- Half Life: ~25 M
- Primary Mode of Decay: IT to U-235
- Spin: 1/2+
- Critical mass: 48 kg (LA-10860-MS; De Volpi), 33.4 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	698.2	608.4		5.865	7.705
elastic	15.04	14.95		2.871	4.566
inelastic		(E-thr = 0.000 MeV)		350.3 -3	1.804
(n,2n)		(E-thr = 5.321 MeV)		542.9 -3	11.56 -3
(n,3n)		(E-thr = 12.190 MeV)		41.79 -3	7.074 -6
fission	584.4	506.8	278.1	2.056	1.235
(n,4n)		(E-thr = 17.970 MeV)			8.408 -9
capture	98.81	86.67	133.0	160.7 -9	89.07 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 2.53E-05 eV Nu_p = 2.4200
- Incident neutron 1E+05 eV Nu_p = 2.4158
- Incident neutron 1E+06 eV Nu_p = 2.5150
- Incident neutron 2E+06 eV Nu_p = 2.6303
- Incident neutron 4E+06 eV Nu_p = 2.8749
- Incident neutron 1.4E+07 eV Nu_p = 4.3857
- Incident neutron fission spectrum average Nu_p = 2.6055

92-U-236

- Atomic Mass: 236.045561897 +- 0.000002091 (amu)
- Excess Mass: 42440.627 +- 1.948 keV
- Binding Energy: 1790415.042 +- 1.974 keV
- Beta Decay Energy: B- -929.469 +- 50.427 keV
- Spin: 0+
- Half Life: 2.342E7 Y

Specific Activity: 6.467E-5 curie/g

Radioisotopic Power: 1.753E-6 W/g

Primary Mode of Decay: Alpha to Th-232

- Decay Energy: 4.572 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 9.6E-8 %
- SF rate (fissions/sec/g) = 0.00230
- Neutron emission rate (N/sec/g) = 0.0041
- Critical mass: Not fissile (C4/TMR2001/200-1), 167 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	13.69	13.09		5.748	7.735
elastic	8.336	8.330		2.757	4.769
inelastic		(E-thr = 0.045 MeV)		326.0 -3	2.256
(n,2n)		(E-thr = 6.578 MeV)		487.3 -3	7.645 -3
(n,3n)		(E-thr = 11.900 MeV)		522.9 -3	66.34 -6
fission	61.29 -3	54.44 -3	7.764	1.659	594.0 -3
capture	5.295	4.703	345.6	366.6 -9	107.6 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-03 eV Nu_p = 2.294
- Incident neutron 1E+05 eV Nu_p = 2.307
- Incident neutron 1E+06 eV Nu_p = 2.425
- Incident neutron 4E+06 eV Nu_p = 2.818
- Incident neutron 1.5E+07 eV Nu_p = 4.267
- Incident neutron fission spectrum average Nu_p = 2.526

92-Uranium-238

- Atomic Mass: 238.050782583 +- 0.000002126 (amu)
- Excess Mass: 47303.664 +- 1.980 keV
- Binding Energy: 1801694.651 +- 2.006 keV

- Beta Decay Energy: B- -147.065 +- 1.145 keV
- Atomic Percent Abundance: 99.2745%
- Half Life: 4.468E+9 Y
- Specific Activity: 3.361E-7 curie/g
- Radioisotopic Power: 8.508E^-9 W/g
- Primary Mode of Decay: Alpha to Th-234
 - Decay Energy: 4.270 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 0.000044 %
- Average neutron yield (Nu)
Nu_prompt = 1.97 +- 0.07
- SF rate (fissions/sec/g) = 0.00551
- Neutron emission rate (N/sec/g) = 0.0108
- Spin: 0+
- Critical mass: none (not fissile)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	12.09	11.77		5.805	7.786
elastic	9.360	9.356		2.704	4.804
inelastic		(E-thr = 0.045 MeV)		698.3 -3	2.595
(n,2n)		(E-thr = 6.179 MeV)		910.0 -3	12.07 -3
(n,3n)		(E-thr = 11.330 MeV)		350.0 -3	61.90 -6
fission	11.77 -6	10.45 -6	2.020	1.136	308.4 -3
capture	2.717	2.414	278.1	1.943 -3	66.40 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 2.53000E-02 eV Nu_p = 2.4481
- Incident neutron 1E+05 eV Nu_p = 2.4552
- Incident neutron 1E+06 eV Nu_p = 2.5194
- Incident neutron 2.9E+06 eV Nu_p = 2.6548
- Incident neutron 5.15E+06 eV Nu_p = 3.0840
- Incident neutron 2E+07 eV Nu_p = 5.1819
- Incident neutron fission spectrum average Nu_p = 2.6010

Neptunium

- Atomic number: 93
- Molar volume: 11.59 cm^3/mole (25 C)
- Density: 20.45 (Np-237, 25 C)
- Melting point: 637 C
- Boiling point: 4000 C

93-Np-237

- Atomic Mass: 237.0481673 +- 0.0000021 amu
- Excess Mass: 44867.501 +- 1.961 keV
- Binding Energy: 1795277.138 +- 1.986 keV
- Beta Decay Energy: B- -220.318 +- 1.298 keV
- Half Life: 2.144E6 Y
- Specific Activity: 7.034E-4 curie/g
- Radioisotopic Power: 2.068E^-5 W/g
- Primary Mode of Decay: Alpha to Pa-233
 - Decay Energy: 4.959 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: <=2E-10 %
- SF rate (fissions/sec/g) = < 5.E-5
- Neutron emission rate (N/sec/g) = < 1.E-4
- Spin: 5/2+
- Critical mass: 60 kg (*Neptunium criticality achieved*), 63.6-81.9 kg (C4/TMR2001/200-1), 18.5 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	192.1	171.2		5.539	7.799
elastic	27.46	27.14		2.606	4.965
inelastic		(E-thr = 0.033 MeV)		105.6E-3	1.321
(n,2n)		(E-thr = 6.657 MeV)		492.5E-3	3.120E-3
(n,3n)		(E-thr = 12.370 MeV)		87.93E-3	14.05E-6
fission	22.49E-3	19.58E-3	7.058	2.247	1.335
capture	164.6	144.0	661.2	228.6E-9	173.4E-3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 2.625
- Incident neutron 1E+05 eV Nu_p = 2.640
- Incident neutron 1E+06 eV Nu_p = 2.775
- Incident neutron 4E+06 eV Nu_p = 3.224
- Incident neutron 2E+07 eV Nu_p = 5.521
- Incident neutron fission spectrum average Nu_p = 2.889

Plutonium

- Atomic number: 94
- Molar volume: 12.061 cm^3/mole

- Density: 19.816 (20 C)
- Melting point: 639.5
- Boiling point: 3230 C

94-Pu-238

- Atomic Mass: 238.0495534 +- 0.0000021 amu
- Excess Mass: 46158.688 +- 1.982 keV
- Binding Energy: 1801274.921 +- 2.008 keV
- Beta Decay Energy: B- -2258.350 +- 50.688 keV
- Half Life: 87.7 Y
 Specific Activity: 17.12 curie/g
 Radioisotopic Power: 0.5678 W/g
 Primary Mode of Decay: Alpha to U-234

- Decay Energy: 5.593 MeV
 Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 1.9E-7 %
- Average neutron yield (Nu)
 Nu_prompt = 2.28 +- 0.10
- SF rate (fissions/sec/g) = 1204.
- Neutron emission rate (N/sec/g) = 2745.

- Spin: 0+
- Critical mass: 12 kg (LA-UR-78-427), 8.95-9.49 kg (C4/TMR2001/200-1), 9 kg (Lovins), 5.26 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	586.7	501.1		6.876	8.829
elastic	28.54	27.85		3.584	6.014
inelastic		(E-thr = 0.044 MeV)		1.155 -3	716.6 -3
(n,2n)		(E-thr = 7.028 MeV)		514.7 -3	3.669 -3
(n,3n)		(E-thr = 12.930 MeV)		54.45 -3	13.71 -6
fission	17.89	15.18	32.69	2.721	1.994
capture	540.3	458.0	153.6	5.861 -9	99.30 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 2.891
- Incident neutron 1E+05 eV Nu_p = 2.906
- Incident neutron 1E+06 eV Nu_p = 3.039
- Incident neutron 4E+06 eV Nu_p = 3.483
- Incident neutron 1.4E+07 eV Nu_p = 4.964
- Incident neutron fission spectrum average Nu_p = 3.148

94-Pu-239

- Atomic Mass: 239.0521565 +- 0.0000021 amu
- Excess Mass: 48583.478 +- 1.971 keV
- Binding Energy: 1806921.454 +- 1.998 keV
- Beta Decay Energy: B- -802.912 +- 2.011 keV
- Half Life: 24110 Y
- Specific Activity: 0.06203 curie/g
- Radioisotopic Power: 0.001929 W/g
- Primary Mode of Decay: Alpha to U-235
 - Decay Energy: 5.245 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 3E-10 %
- Average neutron yield (Nu)
Nu_prompt =
- SF rate (fissions/sec/g) = 7.E-3
- Neutron emission rate (N/sec/g) = 2.E-2
- Spin: 1/2+
- Critical mass: 10.5 kg (LA-10860-MS, WASH-1037 Rev., p. 12), 10.0-10.3 kg (C4/TMR2001/200-1), 7.42 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	1.026 +3	980.2		5.990	7.712
elastic	7.968	7.787		2.984	4.394
inelastic		(E-thr = 0.008 MeV)		366.3 -3	1.460
(n, 2n)		(E-thr = 5.680 MeV)		290.1 -3	4.045 -3
(n, 3n)		(E-thr = 12.710 MeV)		11.50 -3	2.762 -6
fission	747.4	698.3	302.5	2.338	1.800
(n, 4n)		(E-thr = 18.590 MeV)			176.2 -12
capture	270.3	274.2	181.5	7.930 -9	52.94 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 2.53E-02 eV Nu_p = 2.8725
- Incident neutron 1E+05 eV Nu_p = 2.8976
- Incident neutron 1E+06 eV Nu_p = 3.0107
- Incident neutron 4E+06 eV Nu_p = 3.4456
- Incident neutron 1.4E+07 eV Nu_p = 4.9397
- Incident neutron fission spectrum average Nu_p = 3.1231

94-Pu-240

- Atomic Mass: 240.0538075 +- 0.0000021 amu
- Excess Mass: 50121.319 +- 1.947 keV
- Binding Energy: 1813454.935 +- 1.974 keV
- Beta Decay Energy: B- -1378.952 +- 13.790 keV
- Half Life: 6564 Y
- Specific Activity: 0.227 curie/g
- Radioisotopic Power: 0.00707 W/g
- Primary Mode of Decay: Alpha to U-236
 - Decay Energy: 5.256 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 5.7E-6 %
- Average neutron yield (Nu)
 - Nu_prompt = 2.189 +- 0.026
- SF rate (fissions/sec/g) = 478.
- Neutron emission rate (N/sec/g) = 1047.
- Spin: 0+
- Critical mass: 35.7 kg (C4/TMR2001/200-1), 40 kg (Lovins; De Volpi), 15.2 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	291.1	265.2		5.890	7.723
elastic	1.642	1.527		2.716	4.319
inelastic		(E-thr = 0.043 MeV)		432.6 -3	1.950
(n,2n)		(E-thr = 6.561 MeV)		373.1 -3	3.547 -3
(n,3n)		(E-thr = 12.230 MeV)		113.5 -3	14.86 -6
fission	58.77 -3	53.41 -3	8.938	2.254	1.357
(n,4n)		(E-thr = 19.260 MeV)			6.280 -9
capture	289.4	263.6	8.103 +3	800.0 -6	93.28 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 2.794
- Incident neutron 4E+06 eV Nu_p = 3.402
- Incident neutron 1.4E+07 eV Nu_p = 4.922
- Incident neutron fission spectrum average Nu_p = 3.061

94-Pu-241

- Atomic Mass: 241.0568453 +- 0.0000021 amu
- Excess Mass: 52951.039 +- 1.948 keV
- Binding Energy: 1818696.538 +- 1.975 keV
- Beta Decay Energy: B- 20.815 +- 0.199 keV

- Spin: 5/2+
- Half Life: 14.35 Y
Specific Activity: 103.3 curie/g
Radioisotopic Power: 0.01287 W/g
Primary Mode of Decay: Beta to Am-241
 - Decay Energy: 0.021 MeV

Secondary Mode of Decay: Alpha to U-237

- Branch ratio: 0.0025 %
- Decay Energy: 5.140 MeV

Tertiary Mode of Decay: Spontaneous fission

- Branch ratio: <2.E-14 %
- SF rate (fissions/sec/g) = <8.E-4
- Spin: 5/2+
- Critical mass: 12.3-13.0 kg (C4/TMR2001/200-1), 12 kg (Lovins; De Volpi), 9.03 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	1.385 +3	1.275 +3		5.799	7.840
elastic	11.35	11.14		3.290	5.168
inelastic		(E-thr = 0.042 MeV)		2.002 -3	884.0 -3
(n,2n)		(E-thr = 5.262 MeV)		114.3 -3	21.37 -3
(n,3n)		(E-thr = 11.820 MeV)		95.00 -3	18.00 -6
fission	1.012 +3	938.0	572.6	2.298	1.648
(n,4n)		(E-thr = 17.500 MeV)			22.74 -9
capture	361.5	326.1	179.9	105.0 -9	118.2 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 2.930
- Incident neutron 1E+05 eV Nu_p = 2.930
- Incident neutron 1E+06 eV Nu_p = 3.013
- Incident neutron 4E+06 eV Nu_p = 3.490
- Incident neutron 2E+07 eV Nu_p = 5.963
- Incident neutron fission spectrum average Nu_p = 3.142

94-Pu-242

- Atomic Mass: 242.0587368 +- 0.0000021 amu
- Excess Mass: 54713.012 +- 1.966 keV

- Binding Energy: 1825005.887 +- 1.993 keV
- Beta Decay Energy: B- -750.963 +- 0.718 keV
- Half Life: 3.733E5 Y
- Specific Activity: 0.003956 curie/g
- Radioisotopic Power: 0.0001169 W/g
- Primary Mode of Decay: Alpha to U-238
 - Decay Energy: 4.984 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 0.00055 %
- Average neutron yield (Nu)
Nu_prompt = 2.28 +- 0.13
- SF rate (fissions/sec/g) = 805.
- Neutron emission rate (N/sec/g) = 1840
- Spin: 0+
- Critical mass: 85.6 kg (C4/TMR2001/200-1), 90 kg (LA-UR-78-427), 95 kg (Lovins), range 75-100 kg (De Volpi); 22.1 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	27.11	25.12		5.954	7.934
elastic	8.318	8.294		2.922	4.810
inelastic		(E-thr = 0.043 MeV)		279.0 -3	1.900
(n,2n)		(E-thr = 6.336 MeV)		433.3 -3	6.667 -3
(n,3n)		(E-thr = 11.600 MeV)		289.2 -3	43.45 -6
fission	2.557 -3	2.279 -3	5.577	2.027	1.127
(n,4n)		(E-thr = 18.160 MeV)			133.1 -9
capture	18.79	16.82	1.130 +3	800.0 -6	87.87 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 2.790
- Incident neutron 1E+05 eV Nu_p = 2.806
- Incident neutron 1E+06 eV Nu_p = 2.948
- Incident neutron 4E+06 eV Nu_p = 3.421
- Incident neutron 2E+07 eV Nu_p = 5.950
- Incident neutron fission spectrum average Nu_p = 3.070

Americium

- Atomic number: 95
- Molar volume: 17.63 cm³/mole
- Density: 13.67 (Am-241, 25 C)
- Melting point: 1175 C

- Boiling point: 2607 C

95-Am-241

- Atomic Mass: 241.0568229 +- 0.0000021 amu
- Excess Mass: 52930.224 +- 1.957 keV
- Binding Energy: 1817935.000 +- 1.984 keV
- Beta Decay Energy: B- -767.357 +- 1.173 keV
- Half Life: 432.2 Y
- Specific Activity: 3.431 curie/g
- Radioisotopic Power: 0.1147 W/g
- Primary Mode of Decay: Alpha to Np-237
 - Decay Energy: 5.638 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 4E-10 %
- SF rate (fissions/sec/g) = 0.5
- Neutron emission rate (N/sec/g) = 1.
- Spin: 5/2-
- Critical mass: 58 kg (LA-UR-78-427), 57.6-75.6 kg (C4/TMR2001/200-1), 83.5 kg (Lovins; density adjusted), 23 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	614.6	545.4		5.741	7.784
elastic	11.14	10.73		2.722	4.833
inelastic		(E-thr = 0.041 MeV)		49.94 -3	1.340
(n,2n)		(E-thr = 6.610 MeV)		262.4 -3	620.4 -6
(n,3n)		(E-thr = 12.650 MeV)		46.74 -3	10.02 -6
fission	3.018	2.711	13.86	2.660	1.378
capture	600.4	532.0	1.305 +3	229.9 -9	229.6 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 3.235
- Incident neutron 2E+05 eV Nu_p = 3.262
- Incident neutron 1E+06 eV Nu_p = 3.369
- Incident neutron 4E+06 eV Nu_p = 3.769
- Incident neutron 1.4E+07 eV Nu_p = 5.057
- Incident neutron fission spectrum average Nu_p = 3.457

95-Am-243

- Atomic Mass: 243.0613727 +- 0.0000023 amu
- Excess Mass: 57168.280 +- 2.178 keV
- Binding Energy: 1829839.589 +- 2.203 keV
- Beta Decay Energy: B- -8.908 +- 1.434 keV
- Half Life: 7370 Y

Specific Activity: 0.1996 curie/g

Radioisotopic Power: 0.006433 W/g

Primary Mode of Decay: Alpha to Np-239

- Decay Energy: 5.438 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 3.7E-9 %
- SF rate (fissions/sec/g) = 0.27
- Neutron emission rate (N/sec/g) = 0.76
- Spin: 5/2-
- Critical mass: 209 kg (C4/TMR2001/200-1), 38.1 kg (one-group calculation, assuming the same ratio between one-group and multi-group values as Am-241 a 'true' value of 140 kg can be estimated)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	86.10	78.00		5.759	7.854
elastic	7.480	7.428		2.728	4.824
inelastic		(E-thr = 0.042 MeV)		308.5 -3	1.754
(n,2n)		(E-thr = 6.391 MeV)		360.5 -3	3.728 -3
(n,3n)		(E-thr = 11.950 MeV)		221.1 -3	33.16 -6
fission	116.1 -3	103.3 -3	7.585	2.140	1.080
(n,4n)		(E-thr = 18.570 MeV)			2.068 -9
capture	78.50	70.46	1.823 +3	230.7 -9	189.4 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 3.265
- Incident neutron 2E+05 eV Nu_p = 3.292
- Incident neutron 1E+06 eV Nu_p = 3.403
- Incident neutron 4E+06 eV Nu_p = 3.812
- Incident neutron 1.4E+07 eV Nu_p = 5.129
- Incident neutron fission spectrum average Nu_p = 3.496

Californium

- Atomic number: 98
- Molar volume: 16.5 cm³/mole
- Density: 15.1 (Cf-249, 25 C)

- Melting point: 900 C (+- 30 C)
- Boiling point:

98-Cf-249

- Atomic Mass: 249.0748468 +- 0.0000030 amu
- Excess Mass: 69719.351 +- 2.806 keV
- Binding Energy: 1863369.394 +- 2.826 keV
- Beta Decay Energy: B- -1451.000 +- 30.000 keV
- Half Life: 351 Y

Specific Activity: 4.089 curie/g

Radioisotopic Power: 0.1526 W/g

Primary Mode of Decay: Alpha to Cm-245

- Decay Energy: 6.295 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 5.2E-7 %
- SF rate (fissions/sec/g) = 787
- Neutron emission rate (N/sec/g) = 2800
- Spin: 9/2-
- Critical mass: 5.91 kg (C4/TMR2001/200-1), 5.90 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	2.177 +3	1.869 +3		5.817	8.082
elastic	6.223	5.989		2.747	4.952
inelastic		(E-thr = 0.063 MeV)		65.64 -6	1.249
(n,2n)		(E-thr = 5.616 MeV)		662.0 -3	14.19 -3
(n,3n)		(E-thr = 12.620 MeV)		118.0 -3	24.69 -6
fission	1.666 +3	1.430 +3	2.219 +3	2.290	1.741
(n,4n)		(E-thr = 18.660 MeV)			3.046 -9
capture	504.5	433.6	694.9	328.2 -12	120.8 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 3.884
- Incident neutron 1E+05 eV Nu_p = 3.902
- Incident neutron 1E+06 eV Nu_p = 4.061
- Incident neutron 4E+06 eV Nu_p = 4.701
- Incident neutron 1.1E+07 eV Nu_p = 5.880
- Incident neutron fission spectrum average Nu_p = 4.221

98-Cf-251

- Atomic Mass: 251.0795801 +- 0.0000049 amu
- Excess Mass: 74128.333 +- 4.545 keV
- Binding Energy: 1875103.058 +- 4.558 keV
- Beta Decay Energy: B- -375.892 +- 7.107 keV
- Half Life: 898 Y
 Specific Activity: 1.586 curie/g
 Radioisotopic Power: 0.05805 W/g
 Primary Mode of Decay: Alpha to Cm-247
 - Decay Energy: 6.176 MeV
- Spin: 1/2+
- Critical mass: 5.46 kg (C4/TMR2001/200-1), 1.94 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	7.889 +3	6.712 +3		5.838	8.148
elastic	76.09	70.15		2.754	4.814
inelastic		(E-thr = 0.025 MeV)		10.20 -3	862.9 -3
(n,2n)		(E-thr = 5.132 MeV)		268.1 -3	12.34 -3
(n,3n)		(E-thr = 11.780 MeV)		325.2 -3	44.33 -6
fission	4.935 +3	4.196 +3	2.774 +3	2.478	2.430
(n,4n)		(E-thr = 17.400 MeV)			59.29 -9
capture	2.878 +3	2.446 +3	1.604 +3	11.11 -9	27.45 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 4.133
- Incident neutron 1E+05 eV Nu_p = 4.157
- Incident neutron 1E+06 eV Nu_p = 4.374
- Incident neutron 4E+06 eV Nu_p = 5.097
- Incident neutron 1.15E+07 eV Nu_p = 6.917
- Incident neutron fission spectrum average Nu_p = 4.560

98-Cf-252

- Atomic Mass: 252.0816196 +- 0.0000055 amu
- Excess Mass: 76028.139 +- 5.095 keV
- Binding Energy: 1881274.575 +- 5.106 keV
- Beta Decay Energy: B- -1260.000 +- 50.000 keV
- Half Life: 2.645 Y
 Specific Activity: 536.2 curie/g
 Radioisotopic Power: 38.8 W/g (about half fission, half alpha decay)
 Primary Mode of Decay: Alpha to Cm-248
 - Branch ratio: 96.91%
 - Decay Energy: 6.217 MeV

Secondary Mode of Decay: Spontaneous fission

- Branch ratio: 3.09%
- Average neutron yield (Nu)
 - Nu_prompt = 3.7590 +- 0.0048
 - Nu_delayed = 0.0086 +- 0.0010
 - Nu_total = 3.7676 +- 0.004
- SF rate (fissions/sec/g) = 6.13E11
- Neutron emission rate (N/sec/g) = 2.31E12
- Spin: 0+
- Critical mass: 5.87-7.93 kg (C4/TMR2001/200-1), 2.73 kg (one-group calculation)

REACTION	2200-m/s (barns)	Maxw.Avg. (barns)	Res.Integ (barns)	14-MeV (barns)	Fiss.Avg. (barns)
total	64.77	58.49		5.848	8.186
elastic	11.04	11.02		2.758	5.144
inelastic		(E-thr = 0.046 MeV)		10.29 -3	731.5 -3
(n,2n)		(E-thr = 6.195 MeV)		86.60 -3	4.930 -3
(n,3n)		(E-thr = 11.330 MeV)		223.0 -3	35.17 -6
fission	33.03	29.20	110.7	2.770	2.251
(n,4n)		(E-thr = 17.980 MeV)			11.66 -9
capture	20.71	18.27	47.34	185.6 -9	51.29 -3

Average neutron induced Nu_p (prompt neutrons/fission)

- Incident neutron 1E-05 eV Nu_p = 4.060
- Incident neutron 1E+05 eV Nu_p = 4.087
- Incident neutron 1E+06 eV Nu_p = 4.325
- Incident neutron 4E+06 eV Nu_p = 5.119
- Incident neutron 1.5E+07 eV Nu_p = 7.961
- Incident neutron fission spectrum average Nu_p = 4.374